# COMP311:
# *COMPUTER ORGANIZATION!*

Lecture 1: Introduction

Please don’t sit in the back 4 rows ☺

# Welcome! ☺

- Target audience: COMP majors
- Pre-reqs: 210, 211

# What is the course about?

High-level programming languages

```
// High-level (C)
int add3(int a, int b)
{
    return a + b + 3;
}
```

Easy for humans to read/write

Assembly
Low-level languages

```
# Matching RISC-V assembly
# a0 = a, a1 = b;  return in a0

add   a0, a0, a1   # a0 = a0 + a1
addi  a0, a0, 3    # a0 = a0 + 3
ret                 # return
```

Human readable

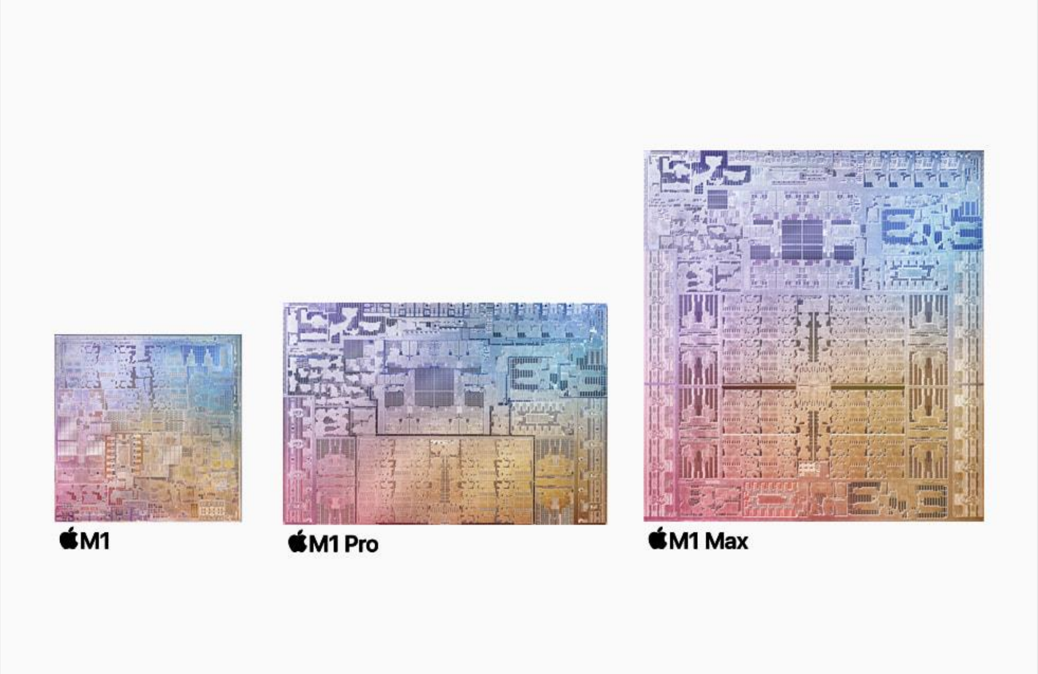
Machine code

```
0000000 01011 01010
000 01010 0110011

000000000011 01010
000 01010 0010011

000000000000 00001
000 00000 1100111
```

Machine-readable

# Why should we care?

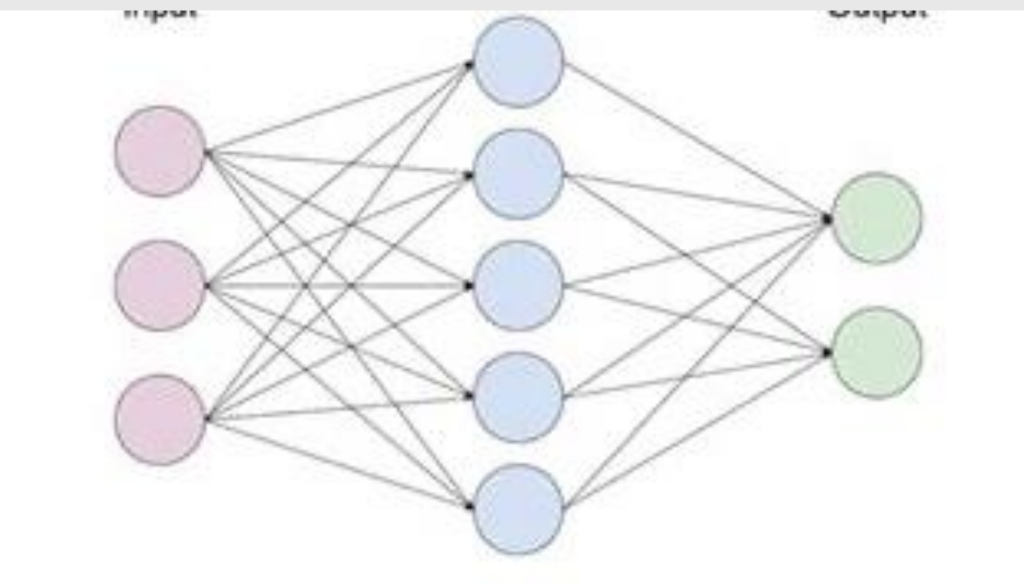
Intel Core i9-13900K



Apple M1 Pro

# Artificial Intelligence

Advancements in computer architecture have been a driving force behind the advancement of AI technologies



# Goals of this Course

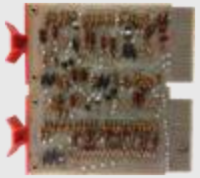
- How does a computer work?
- How is data represented in a computer?
  - Numbers, strings, arrays, photos, music
- How is a **program** represented in a computer?
- What does a computer do with my program?
- How is data stored? How is data processed?
- Are there any limits to what a computer can do?

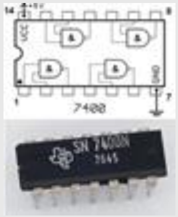
# Logic Circuits and Digital Hardware

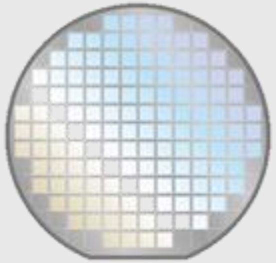
- Logic circuits are used to build computer hardware, as well as many other types of systems. All such systems are broadly classified as digital hardware.
- *Digital* derives from how *information* is represented as discrete ranges of electrical signals. Using discrete ranges provides robustness and scalability.

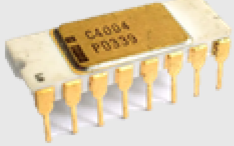
# Digital Logic is Relatively New + Revolutionary!

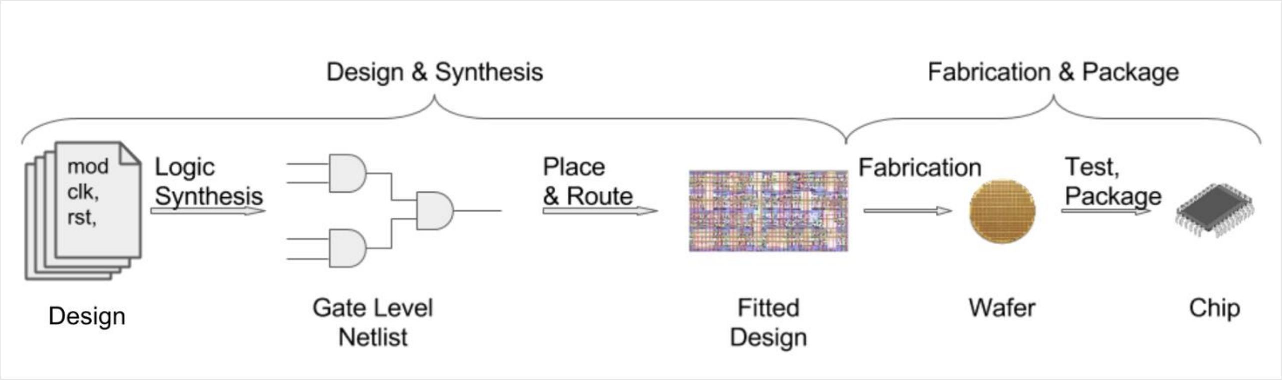
- Digital hardware technology has evolved dramatically over the past 75 years!
  - *In the 1960s logic was built with discrete components, transistors and resistors.*
  - *Integrated circuits (ICs) made it possible to place a number of transistors on a single chip.*
  - *By 1970 it was possible to implement all circuitry needed to realize a microprocessor on a single chip.*
  - *Complexity has exploded!*



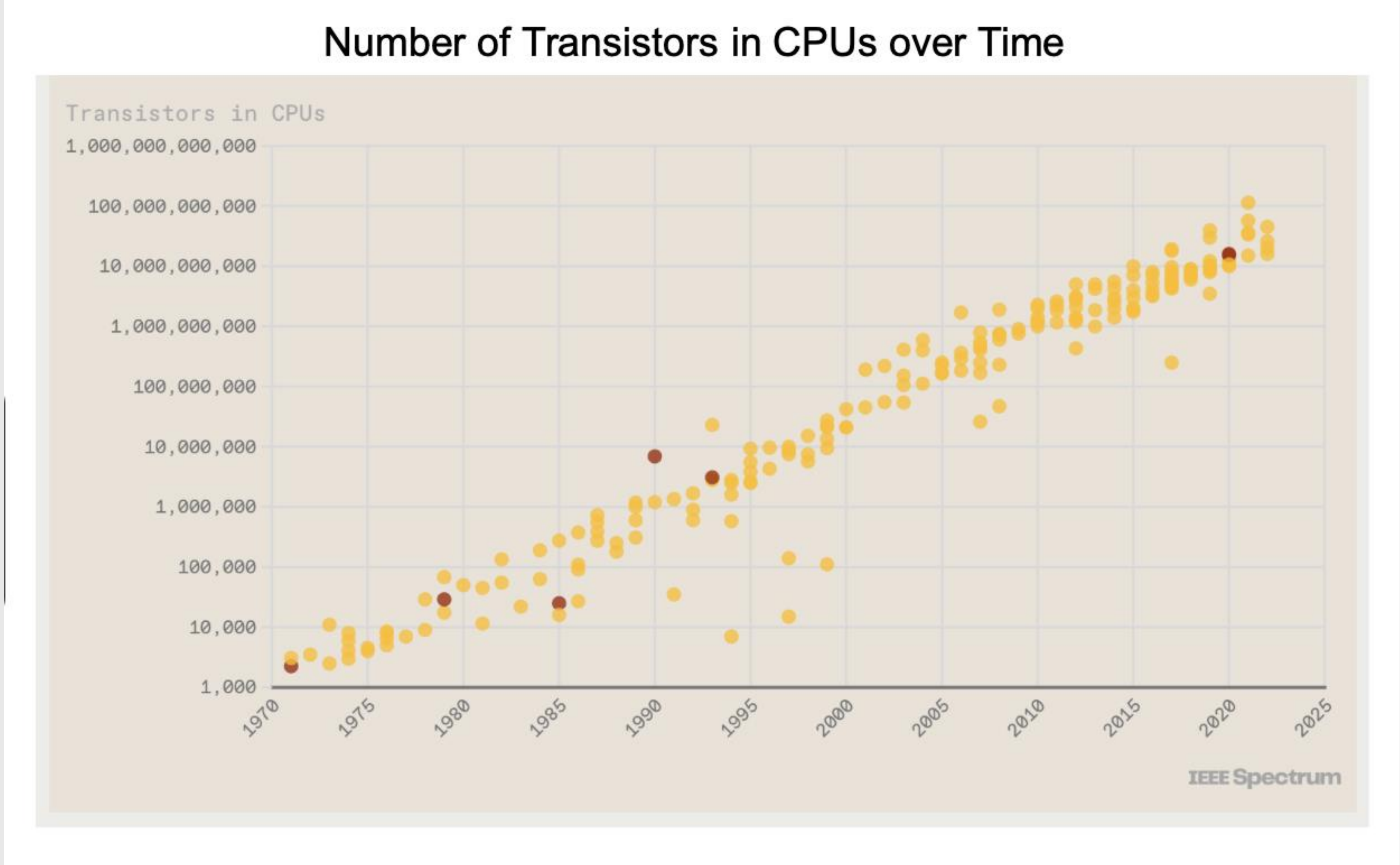








# Moore’s Law!


Number of Transistors in CPUs over Time
Transistors in CPUs
1,000,000,000,000
100,000,000,000
10,000,000,000
1,000,000,000
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
IEEE Spectrum

# Course Theme #1: Demystify Computers!

Strangely, most people seem to be afraid of computers.

People only fear things they do not understand!

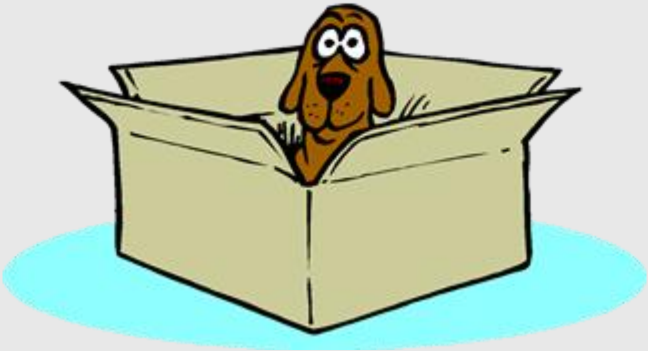
*“I do not fear computers, I fear the lack of them.”*
*- Isaac Asimov (1920 - 1992)*

*“Fear is the main source of superstition, and one of the main*
*Sources of cruelty. To conquer fear is the beginning of wisdom.”*
*- Bertrand Russell (1872 -1970)*

*“Nobody knows exactly what’s going on because of computers!”*
*- Donald Trump*

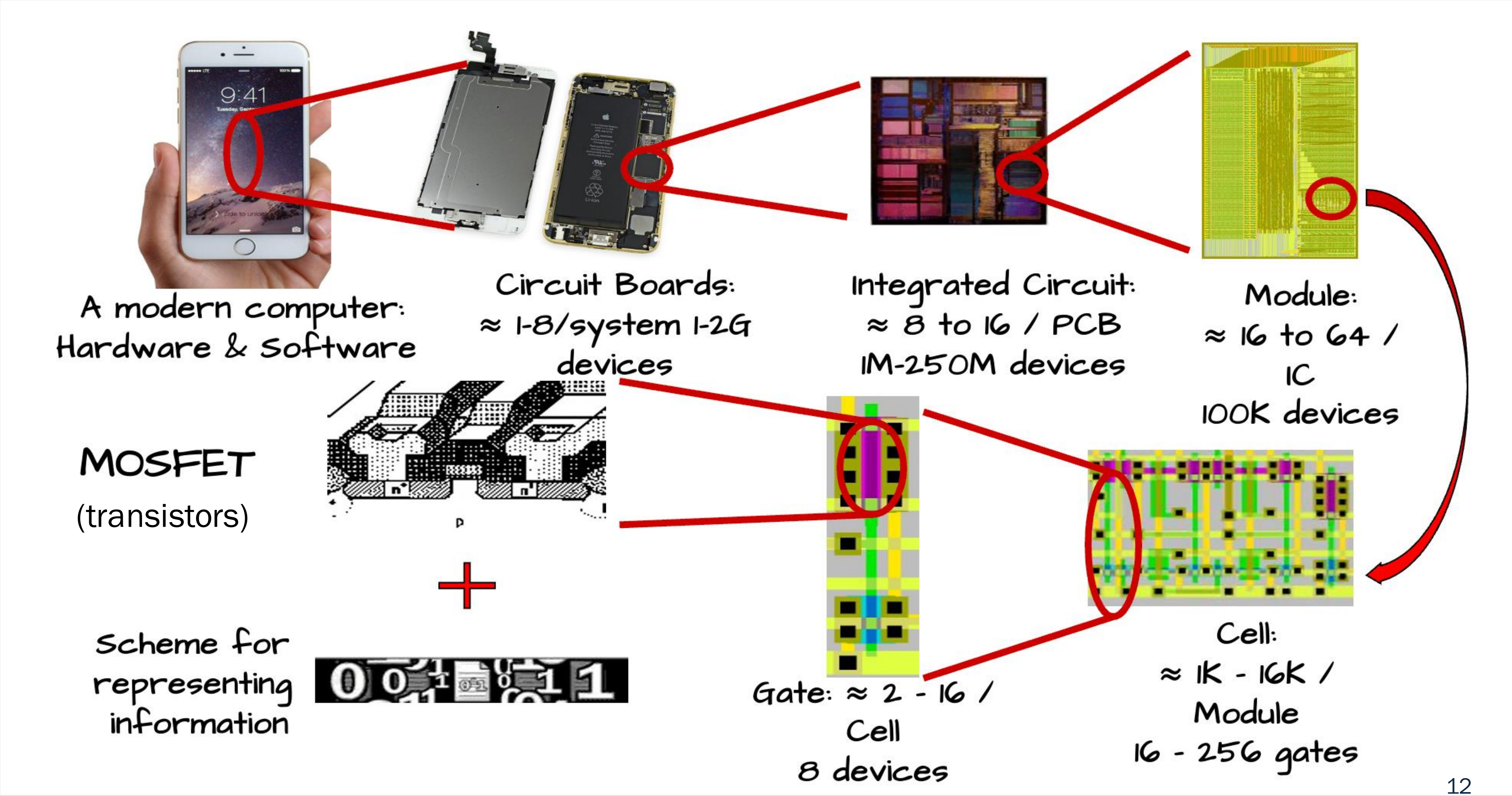
# Course Theme #2: The Power of Abstraction!

Define a function, develop a roust implementation, and then put a box around it, and then reuse it (over and over!).



Abstraction enables us to create unfathomable systems, including computer hardware and software.

# Course Theme #2: The Power of Abstraction!



A modern computer:
Hardware & Software

Circuit Boards:
≈ 1-8/system 1-2G
devices

Integrated Circuit:
≈ 8 to 16 / PCB
1M-250M devices

Module:
≈ 16 to 64 /
IC
100K devices

MOSFET

(transistors)

+

Scheme for
representing
information

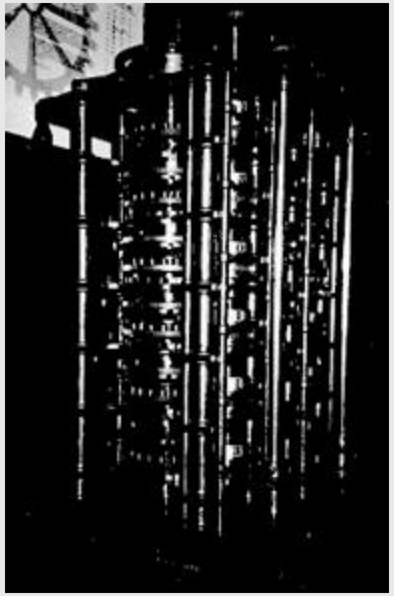
Gate: ≈ 2 - 16 /
Cell
8 devices

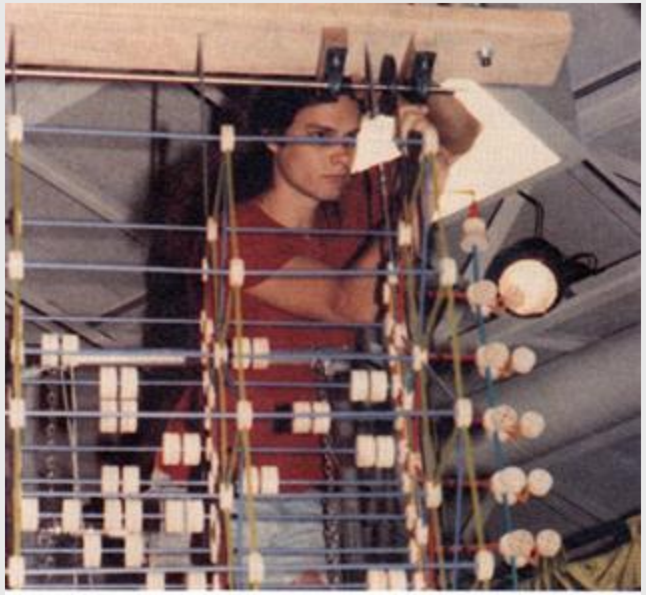
Cell:
≈ 1K - 16K /
Module
16 - 256 gates

# Computational structures!

- What are the fundamental elements of computation?

- Can we define computation independent of implementation or the technology that it is implemented with?





*Edward Hardebeck helps to assemble the Tinkertoy computer*

# Recall: Goals of this Course

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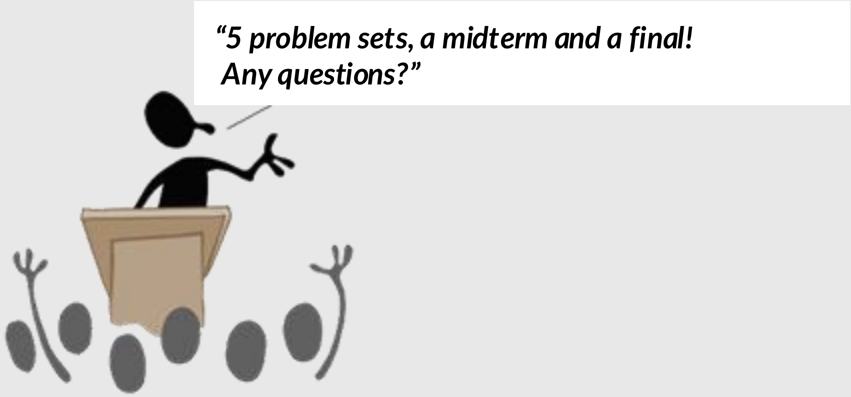
- *Digital* derives from how *information* is represented as discrete ranges of electrical signals. Using discrete ranges provides robustness and scalability.

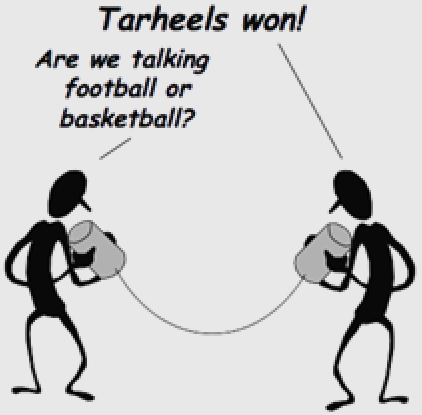
# What does Digital Logic do?

- It processes bits: 1s and 0s
- It implements abstract logic functions
- It is robust, stable, and repeatable
- It doubles every two years.
- It represents, transforms, and stores *information*

# What is “Information”?

**information, n.** *Knowledge communicated or received concerning a particular fact or circumstance.*





**A Computer Engineer’s definition:**

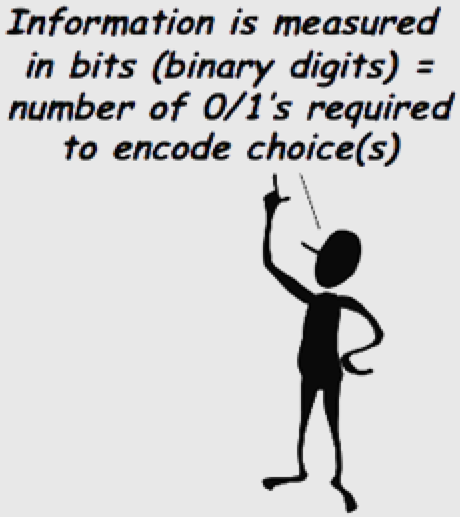
*Information resolves uncertainty.*

*Information is simply that "stuff" which cannot be predicted. The less likely a message is, the more information it conveys.*

# Quantifying Information

Suppose you're faced with *N* equally probable choices, and I give you a fact that narrows it down to *M* possibilities. Then you've been given:

**$\log_2(N/M)$ bits of information**



Information is measured in bits (binary digits) = number of 0/1's required to encode choice(s)

Examples:

- Outcome of a coin flip: $\log_2(2/1) = 1$ bit
- The roll of one die?
- Someone tells you that their 8-digit phone number is a palindrome?

Information is the theoretical underpinning of why digital computers use bits! ☺

# An exercise: How many bits?

With 1-2 classmates, take 5 minutes to answer question 1 on your worksheet.

You can take “N” to represent the number of students in this class, and “M” to be the number of students with the last name Ryan.

# What do programs really do?

At this point in your CS career, you look at a program specification and figure out what it does!

Q: What does this do? What is your strategy for figuring it out?

Hint: Try f(36), f(64), f(100)

```
int f(int x) {
    int r;
    int odd = 1;
    for (r = 0; x >= odd; r++) {
        x -= odd;
        odd += 2;
    }
    return r;
}
```

# How does a computer do it?

What would a computer do with this program specification?

```
int f(int x) {
    int r;
    int odd = 1;
    for (r = 0; x >= odd; r++) {
        x -= odd;
        odd += 2;
    }
    return r;
}
```

```
f:       mv    t0,a0
         li    t1,1
         li    a0,0
         blt   t0,t1,return
loop:    sub   t0,t0,t1
         addi  t1,t1,2
         addi  a0,a0,1
         bge   t0,t1,loop
return:  ret
```

It translates it into a series of simple instructions!

# Are there limits to computation?

- Will some new instruction be invented that fundamentally changes how fast computers solve problems?
- Can computers solve *any* well-specified problem?
  - COMP455
- Can we predict how long it will take for a computer to solve a given problem?
  - COMP210, COMP550
- Does there exist a new model of computation?

# ADMINISTRATIVE DETAILS

# Syllabus!

Course site:
https://www.cs.unc.edu/~kakiryan/teaching/311-fa25/311-fa25.html

Or

https://tinyurl.com/comp311-fa25

# Course Structure

- Assessment (60%):
  - *6x Quizzes* (QZ)*: 48%*
  - *Final Exam* (FN)*: 12%*

Your final can replace up to two of your lowest quiz scores.

- Practice and Preparation (40%):
  - *6x Written Assignments* (WA)*: 20%*
  - *5x Labs* (LAB)*: 20%*

Your lowest WA grade will be dropped.

# Extensions + Late Days

- You have 8 days to use on any assignment in the course, with no explanation needed.
- You may request extensions for illness or personal life events so you don’t have to use up your late days.
  - Extension form is linked in the syllabus
- If you are not sure if something qualifies for an extension, just fill out the form anyway, and we will get back to you.
- *You will not be penalized for submitting the assignment within the provided grace period if you receive an extension!*

# Gradescope

- Make sure you are enrolled!

# The Team!

- LAs:
  - *Zhi Yang, Jules Kim, Ram Ariga, Ben Chesser, Michelle Jon, Mana Rose, Trey Anderson, Aashvi Jain, John Shanahan*

- LA office hours will be held in CSXL RM SN137. Time TBD!
  - I will send out an announcement once we schedule them!
- My office hours are Mondays 10-12 in FB114.

# HEALTH & SAFETY

# Face Masks

- Optional
- Use a mask often!

# Emergency Procedures

- Evacuate (fire, chemical hazard)
- Shelter in place (weather related)
- Secure in place (armed and dangerous assailant)
  - run, hide (secure in place), fight

# Acknowledgements

- Optional Textbook 1: Computer Organization and Design RISC-V Edition: The Hardware Software Interface by David Patterson and John Hennessey
- Textbook 2: The RISC-V Reader: An Open Architecture Atlas by David Patterson and Andrew Waterman.
- Connor McMahon, Leonard McMillan, Montek Singh

# 211 REVIEW ☺

# Base

- A base is the number of different digits that a system can use to represent numbers
- Binary is base 2 because it has the digits 0 and 1
- Decimal base 10 because it has the digits 0-9
- Hex is base 16 because it has the digits 0-F

# Binary Notation

- Always prepend binary numbers with “0b” or add a subscript of 2
  - *Ex: 0b 1001 or $1001_2$*
- Place binary numbers in groups of four to make it easier to read
  - *Ex: 0b 1010 1111 0101 or 0b1010_1111_0101*
  - *If you cannot evenly break up the number into groups of four, start making the groups from the right*
    - Ex: 0b10_1010_0011

# Hex Notation

- Always prepend hex numbers with “0x” or add a subscript of 16
  - *Ex: 0xE2A or $E2A_{16}$*

# Decimal Notation

- You can indicate that a number is a decimal value by adding a subscript of 10
  - *Ex:* $\mathit{54}_{\mathit{10}}$
- If a number does not have a leading “0b” or “0x” and does not have a subscript, it is assumed to be a decimal value

# Overflow

- Overflow occurs when the result of the operation cannot be represented with the given number of bits
- When adding two unsigned numbers, overflow occurs when the carry-out of the operation is 1

# Binary Addition and Overflow

Take 5 minutes to answer question 3 on your worksheets!

# Binary Addition and Overflow

$$\begin{array}{r} 1010_2 \\ +\ 0101_2 \\ \hline \end{array}$$

$$\begin{array}{r} 1001_2 \\ +\ 0111_2 \\ \hline \end{array}$$

$$\begin{array}{r} 1010_2 \\ +\ 0111_2 \\ \hline \end{array}$$

$$\begin{array}{r} 0110_2 \\ +\ 0110_2 \\ \hline \end{array}$$